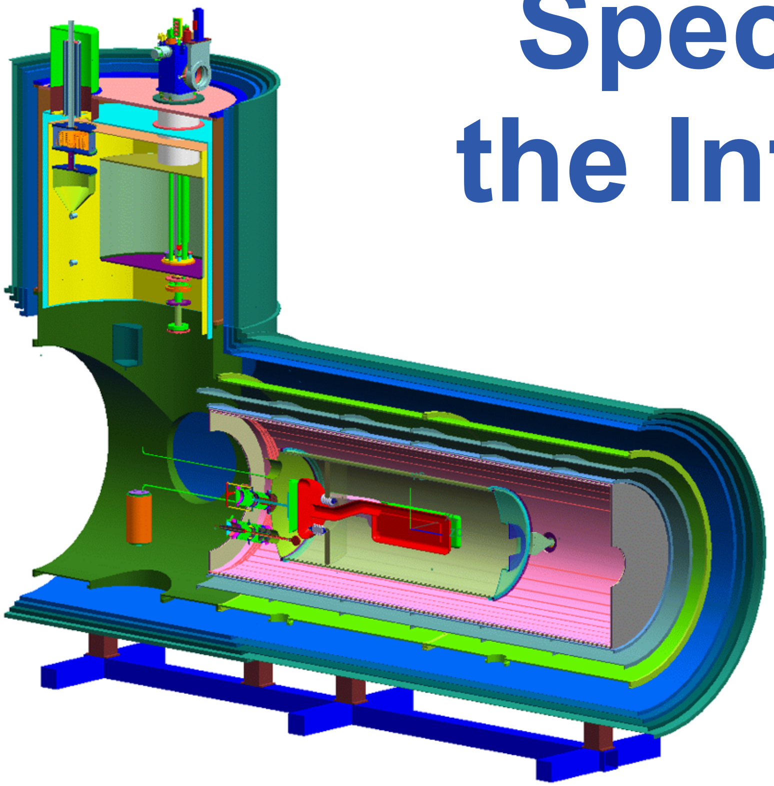

Specifications for the Integrated Tests

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Overall Challenge

- To bring together the tested components from the individual work packages and integrate them to form a complete apparatus.
- Three individual subsystems must be integrated into the fourth subsystem (cryogenic vessel) before we can take data:
  - Measurement cell and high voltage system
  - Cryogenic magnetic shields and coils
  - ^{3}He polarizer, purifier, and transport system
- We estimate that each cooldown cycle will take approximately two months. This drives our schedule. We want to keep the number of cooldowns to a minimum!

Planning Assumptions

- The subsystems arrive at ORNL fully tested.
- The subsystems will be incorporated sequentially in the cryovessel.
  - Measurement cell and high voltage system
  - Cryogenic magnetic shields and coils
  - ^{3}He polarizer, purifier, and transport system
- We require the ability to integrate and test all subsystems w/o the external magnetic shield.
- Integration of the DAQ and other external subsystem components will occur in parallel as the systems are integrated. They are ignored in this talk.
- Dedicated cryogenic personnel will be hired by ORNL.

Integration Schedule

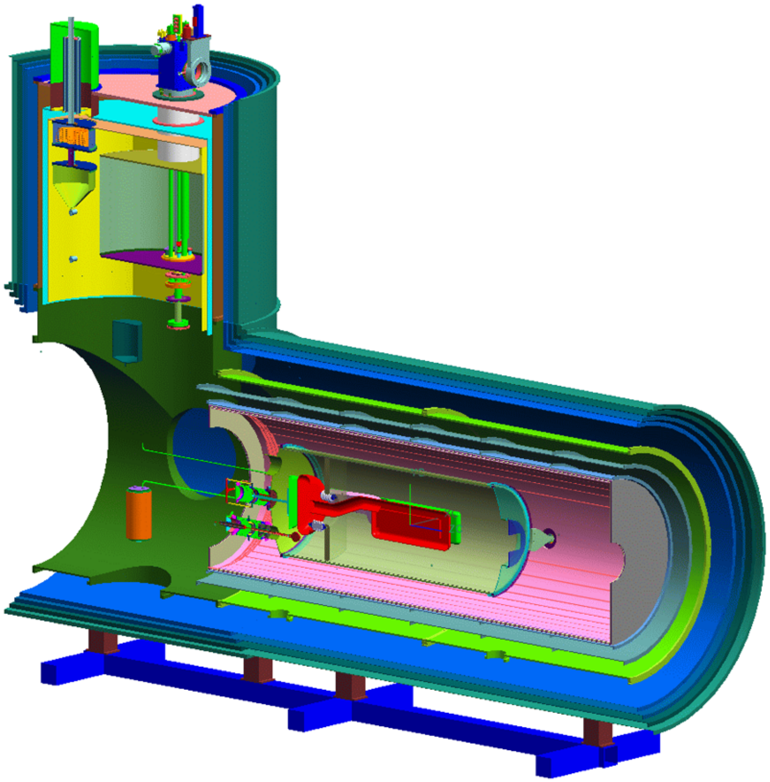
- Everything is dominated by the number of cooldown cycles required for successful commissioning. Our best guesses for the number of cooldowns are:
  - 3 - coil package
  - 4 - insert
  - 4 - 3He components
  - 5 - integrated tests and commissioning (w/ beam, B-shield)
- Debugging of systems before they arrive is essential. Tests that could take one week in a smaller test apparatus will take about two months in the main cryostat.

Goals of this Discussion

- DOE recommendation:
  - "Prior to CD-2, develop testing plans that identify the activities and goals for the performance tests of the subsystems at the individual institutions and the assembly site."
- Insure we meet the CD-4 requirements
- Remind everyone of what we have told DOE
- Specify some internal benchmarks that are more stringent than these DOE minimums

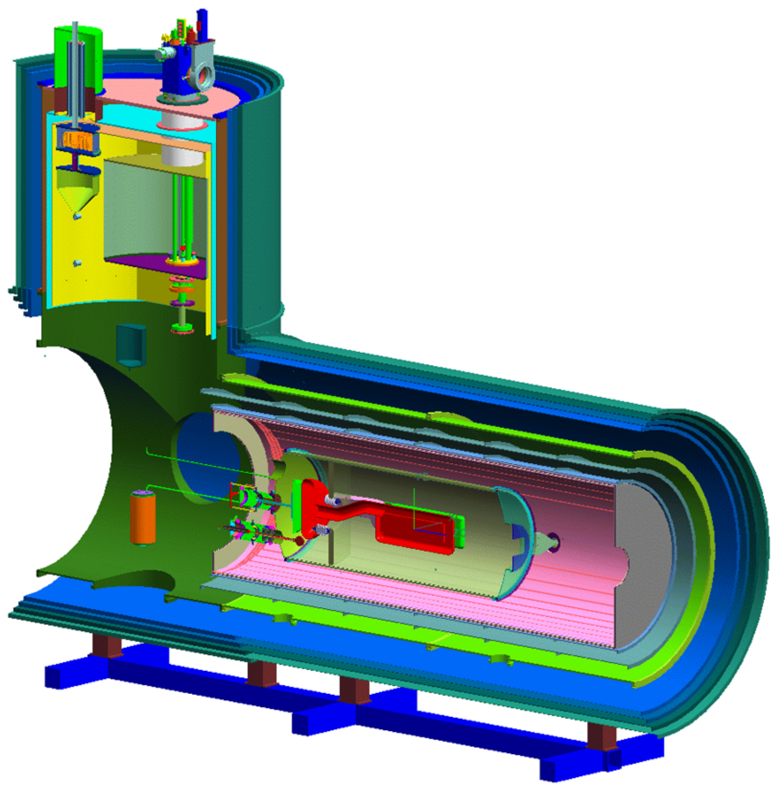
Major Systems

- Cryovessel
- High voltage system and detector insert
- Magnetic shields and coil package
- ^{3}He systems



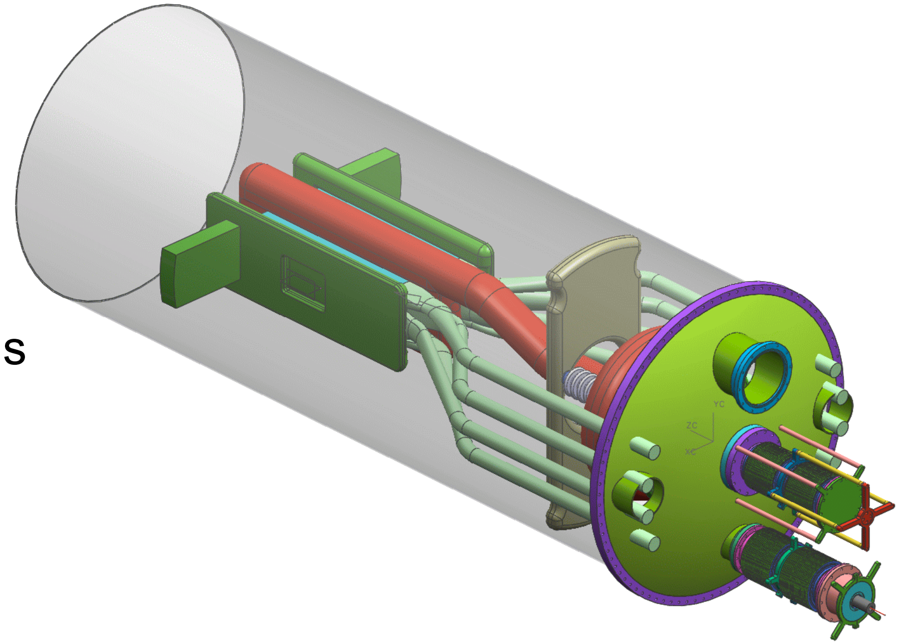
0. Cryovessel

- Major components:
  - Helium liquefier and gas storage system
  - Liquid helium transfer system
  - 300 K outer vacuum can
  - 50 K temperature shield
  - 4 K temperature shield
  - 1200 l central volume
  - Dilution refrigerator(s)
  - Instrumentation and controls



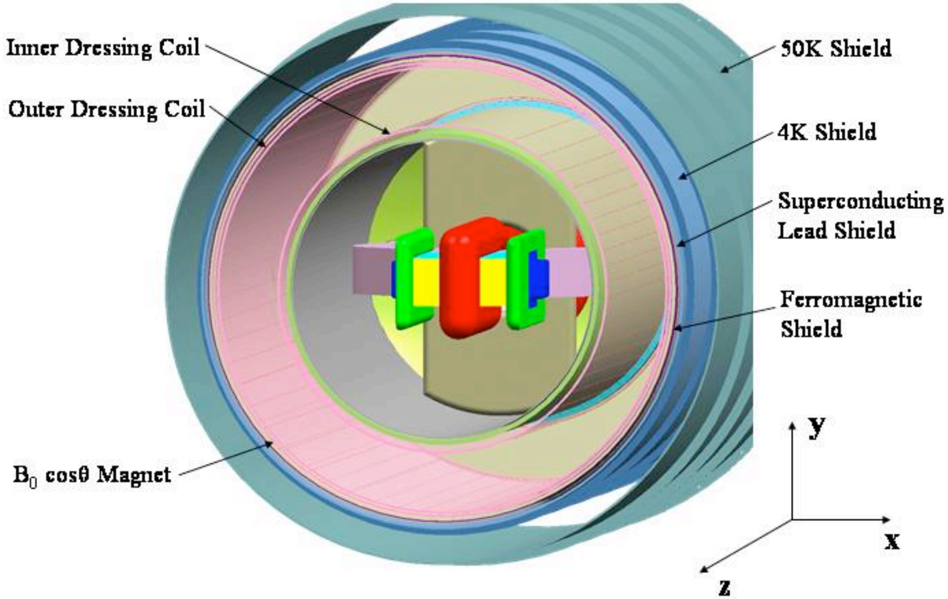
1. High Voltage System and Measurement Cell

- Major components:
  - High voltage system (T < 500 mK)
    - capacitor plates
    - cell electrodes
    - high-voltage feedthroughs
    - power supplies
  - Detection system (T < 500 mK)
    - dTPB coated measurement cells
    - light collection optics
    - light guide feedthroughs
    - PMT's or equivalent



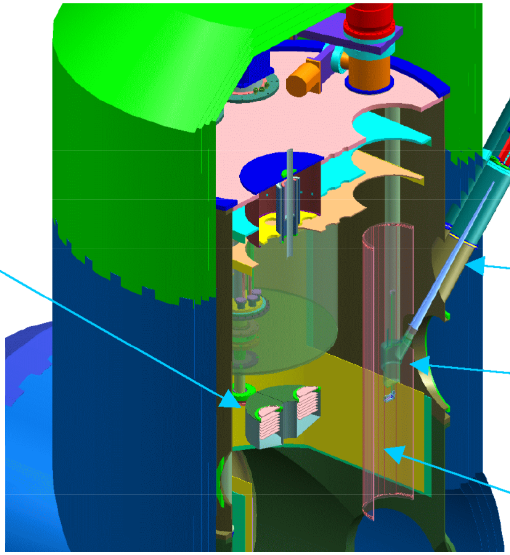
2. Cryogenic Shields and Coil Package

- Major components:
  - Coil package (T = 4K)
    - cos(Θ) magnet
    - inner dressing coil
    - outer dressing coil
    - trim coils
    - coil support frames
  - Shielding package (T = 4K)
    - superconducting shield
    - ferromagnetic shield
  - ^{3}He coil package and shields (T = 4K)
  - Instrumentation for field monitoring



3. ^{3}He Injector and Purifier

- Major components:
  - atomic beam source (T < 500 mK)
    - source itself
    - interface to the apparatus
    - ^{3}He collection volume
    - transport coils and shields *
  - ^{3}He transport system (T < 500 mK)
    - valves and tubing
    - expansion volumes
    - ^{3}He depolarization in cell
  - ^{3}He purifier (T < 500 mK)
    - charcoal pumps
    - volume displacement for level control
  - Instrumentation and controls



* Cryogenic shields and coil package subsystem

CD-4 Requirements as Presented to DOE

- Cryogenic vessel
  - Demonstrated to cool the central detector volume to 500 mK
  - Operated with the magnet coil package in place
- Magnet coil package
  - $\langle dB/dx \rangle / B0 < 10^{-5}$/cm at 77 K *
- Four-layer magnetic shield
  - Shielding factor of 10^{-4} *

* Tests performed offsite

CD-4 Requirements as Presented to DOE (cont.)

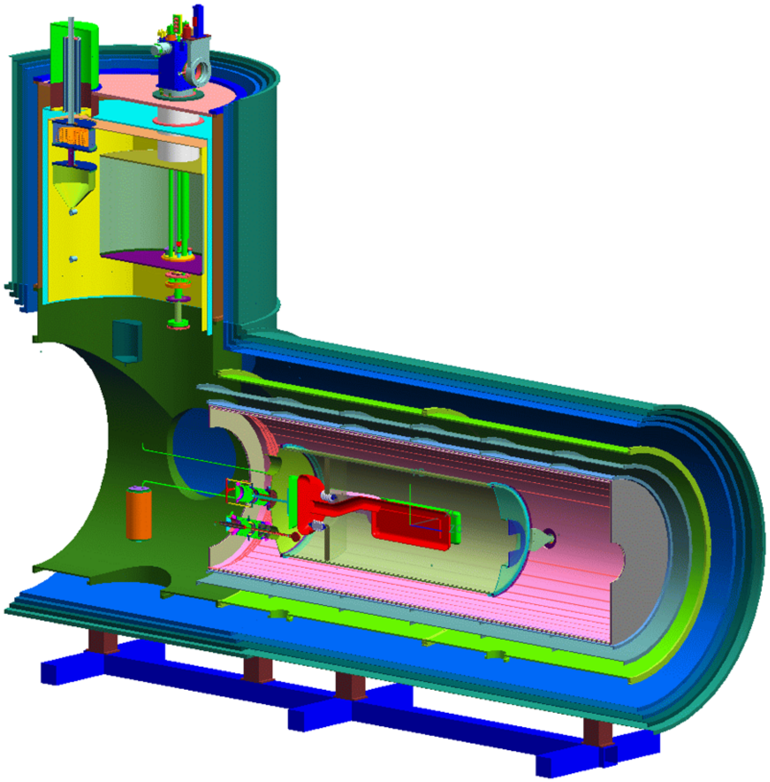
- Central detector insert
  - High voltage holds 5 kV/cm with a leakage current <10 nA
  - Mean number of photoelectrons from 750 keV of energy deposition is ≥ 4
  - SQUID noise <100 $\mu\Phi_0/\sqrt{\text{Hz}}$ in 10 Hz bandwidth that, based on independent tests, implies a S/N>1
  - Neutron storage time in similar cell demonstrated to be >100 sec in an independent test

CD-4 Requirements as Presented to DOE (cont.)

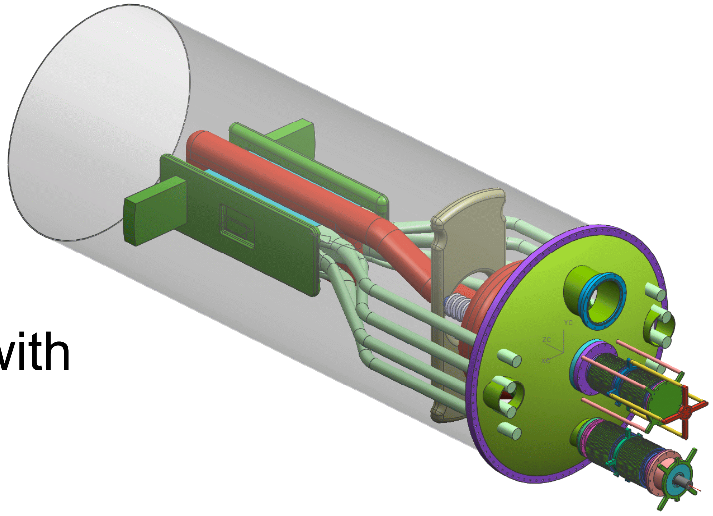
- ^{3}He services
  - Produces $\geq 10^{11}/cm^3$ of ≥70%-polarized ^{3}He in the collection volume as seen with a SQUID*
  - Purifier reduces the ^{3}He concentration to less than 1 part in 10^{11}*
  - ^{3}He demonstrated to move between volumes with a time constant of 500 s or less*
  - Valves shown to operate over 500 cycles*
  - Installed in the cryogenic vessel
- Neutron guides
  - Flux out/MW ≥ 4×10^5 n/Å/cm^2/s/MW @ 8.9 Å with a polarization ≥ 70%

Cryovessel (starting point)

- Demonstrated to cool the central detector volume to a temperature of < 500 mK with an internal goal of < 250 mK
  - Liquefier installed and operational
  - Dilution refrigerator(s) (DR) installed and has >80 mW of cooling power at 300 mK
  - Heat loads to DR/shields characterized and under control
  - Central 1200 l helium volume installed and leak tight
  - Dewar vacuum tight with appropriate temperature shields
  - Fully implemented with diagnostic sensors

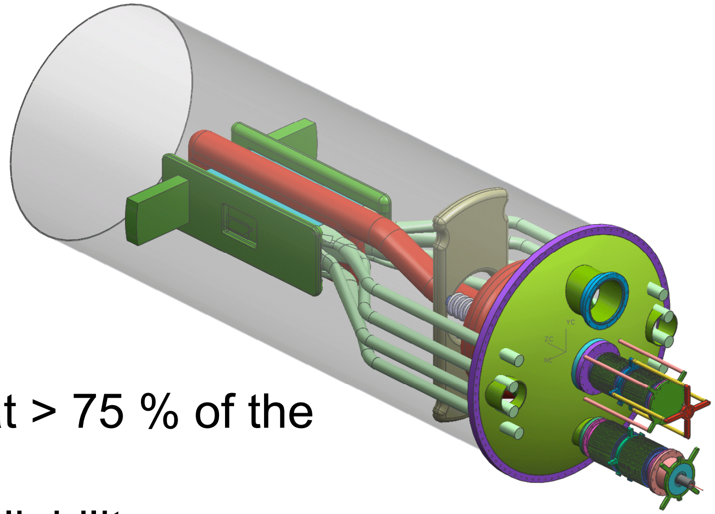


High Voltage System and Measurement Cell



- Before arrival:
  - Design fully incorporated into the cryovessel design and vetted from a cryogenics standpoint (ie. it will fit in and cool down). Implemented with appropriate sensors.
  - Assembly shown to meet the CD-4 requirements at 0.5 K:
    - High voltage system shown to hold 5 KV/cm with a leakage current of <10 nA, with the cell and lightguides in place
    - The mean number of photoelectrons from 750 keV of energy deposition is > 4, tested using a radioactive source place in each cell while the cell if full of helium.

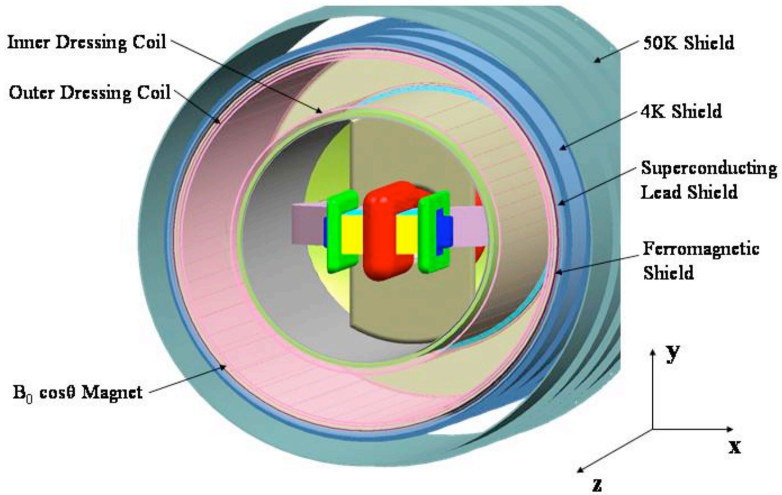
High Voltage System and Measurement Cell



- Before arrival (cont.):
  - Assembly shown to meet our internal requirements at 0.5 K:
    - High voltage feedthroughs tested for reliability.
    - High voltage system shown to hold at > 75 % of the R&D value at 500 mK.
    - Light guide penetrations tested for reliability.
    - The mean number of photoelectrons from 750 keV of energy deposition is > 12, tested using a radioactive source place in each cell while the cell if full of helium.
    - High-voltage and lightguide feedthroughs shown to impart a total heat load of less than 20 mW into the central volume.
    - UCN storage time in cell measured to be > 200 s
    - Measured electric field spark rate < 0.5/year
    - Electric field uniformity measured to be < 10^{-2}

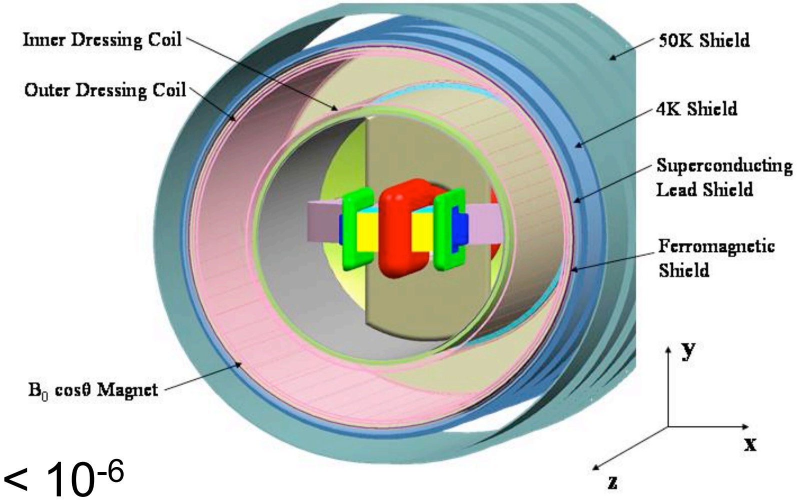
Cryogenic Shields and Coil Package

- Before arrival:
  - Design fully incorporated into the cryovessel design and vetted from a cryogenics standpoint (ie. it will fit in and cool down). System is implemented with appropriate sensors.
  - Assembly shown to meet the CD-4 gradient requirement at 77 K and high field:
    - $\langle dB/dx \rangle / B_0 < 10^{-5}$/cm



Cryogenic Shields and Coil Package

- Before arrival (cont.):
  - Coil assembly shown to meet our internal requirements:
    - High field uniformity test at 300 K (horizontally and vertically)
    - High field uniformity test at 77 K (vertically)
    - Low field uniformity test at 300 K (horizontally in magnetic shields)

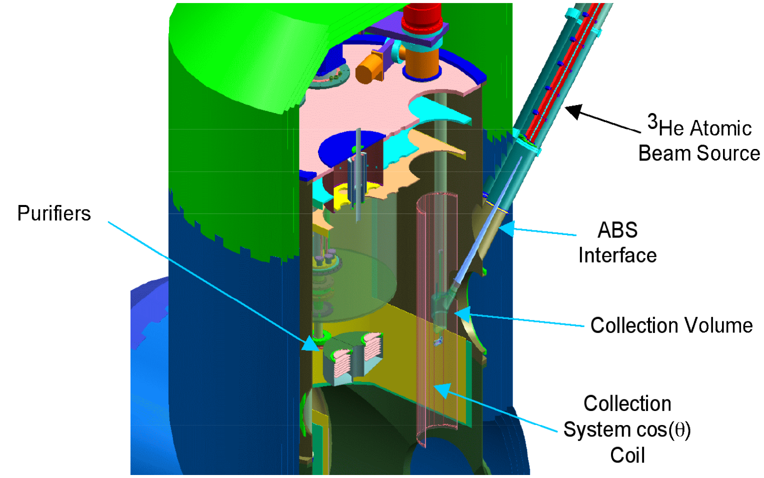


    - $\langle dB/dx \rangle / B_0 < 10^{-5}$/cm
    - B_0 uniformity < 2 x 10^{-3}
    - Uniformity of other fields < 5 x 10^{-3}
    - Power supply ripple measured to be < 10^{-6}

    - Simulation to show Eddy current heating at 4 K < 100 mW, central volume < 5 mW
    - Calculated heat load at 4.2 K is < 500 mW

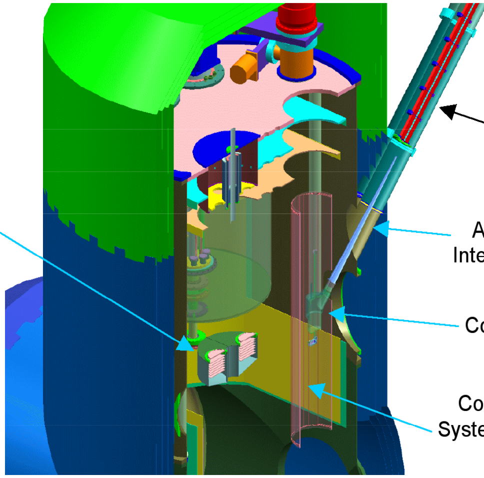
3He Injector and Purifier

- Before arrival:
  - Design fully incorporated into the cryovessel design and vetted from a cryogenics standpoint (ie. it will fit in and cool down). Implemented with appropriate sensors.
  - Assembly shown to meet the CD-4 requirements at 0.5 K:
    - ABS produces ≥ $10^{11}/cm^3$ of ≥ 70%-polarized ^3He in the collection volume as seen with a SQUID
    - Purifier reduces the ^3He concentration to less than 1 part in 10^{11}
    - ^3He demonstrated to move between volumes with a time constant of 500 s or less
    - Valves working and shown to operate over 500 cycles



3He Injector and Purifier

- Before arrival:
  - Assembly shown to meet our internal requirements at 0.5 K:
    - Purifier and injection/transport system shown to work independently.
    - Injection ^{3}He polarization in the collection volume as seen with a SQUID is > 90%.
    - Valves working and shown to operate reliably over 5000 cycles.
    - ^{3}He polarization lifetime in the measurement cells is measured to be greater than 1000 s.
    - Polarized 3He from the ABS fills the collection volume and is then transported along a similar impedance to a full size measurement cell.
    - Operation of the purifier demonstrated, including the regeneration of the charcoal adsorption pumps.



Summary

- Reminder: the duration and costs are dominated by the length and number of cooldowns.
- Subsystems must be fully vetted before we attempt to assemble them into the main apparatus!
- In working up the CD-2 documentation, make sure you have incorporated the appropriate tests (and costs) into the WBS. The assembly subgroup assumes systems arrive fully tested and are ready to incorporate into the cryovessel. Any assembly jigs, etc. should either ship with the subsystem or be included in the infrastructure subgroup.